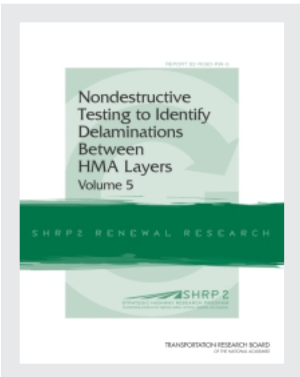

Nondestructive Testing to Identify Delaminations Between HMA Layers, Volume 5 - Field Core Verification

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The Second
STRATEGIC HIGHWAY RESEARCH PROGRAM

SHRP 2 REPORT S2-R06D-RW-5

Nondestructive Testing to Identify Delaminations Between HMA Layers

Volume 5

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The Second Strategic Highway Research Program

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The need for SHRP 2 was identified in *TRB Special Report 260: Strategic Highway Research: Saving Lives, Reducing Congestion, Improving Quality of Life*, published in 2001 and based on a study sponsored by Congress through the Transportation Equity Act for the 21st Century (TEA-21). SHRP 2, modeled after the first Strategic Highway Research Program, is a focused, time-constrained, management-driven program designed to complement existing highway research programs. SHRP 2 focuses on applied research in four areas: Safety, to prevent or reduce the severity of highway crashes by understanding driver behavior; Renewal, to address the aging infrastructure through rapid design and construction methods that cause minimal disruptions and produce lasting facilities; Reliability, to reduce congestion through incident reduction, management, response, and mitigation; and Capacity, to integrate mobility, economic, environmental, and community needs in the planning and designing of new transportation capacity.

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This work was sponsored by the Federal Highway Administration in cooperation with the American Association of State Highway and Transportation Officials. It was conducted in the second Strategic Highway Research Program, which is administered by the Transportation Research Board of the National Academies. The project was managed by Dr. Monica Starnes, Senior Program Officer for SHRP 2 Renewal.

The team recognizes the technical input of the research team's expert panel. In addition to providing the team with valuable comments, the highway agency team members assisted with identification and support of field evaluation sites. The members of the expert panel are Jim Musselman, the Florida Department of Transportation (DOT); Kim Willoughby, the Washington State DOT; Andrew Gisi, the Kansas DOT; Nadarajah Sivaneswaran, FHWA; John Harvey, University of California, Davis; and Harold Von Quintus, Applied Research Associates.

The team recognizes the support of the NDT technology firms that expended their own resources to provide NDT equipment and software to the study. The companies that supported the project were Geophysical Survey Systems, Inc.; MALA AB; 3d-Radar (a Curtiss-Wright Company); Geomedia Research and Development; Olson Instruments, Inc. and Olson Engineering Inc.; and Infrared Cameras, Inc. The study could not have been completed without their generous assistance.

The team especially recognizes the efforts of the hardware and software development staffs of 3d-Radar and Olson Instruments, Inc., for improving the capabilities of their NDT technologies to meet the needs of highway agencies.

FOREWORD

Monica A. Starnes, PhD, *Senior Program Officer, Renewal*

Asphalt pavements with delamination problems experience considerable early damage because delaminations provide paths for moisture damage and the development of damage such as stripping, slippage cracks, and pavement deformation. Early detection of the existence, extent, and depth of delaminations in asphalt pavements is key for determining the appropriate rehabilitation strategy and thus extending the life of the given pavement.

This report presents the findings of the first two phases of SHRP 2 Renewal Project R06D, Nondestructive Testing to Identify Delaminations Between HMA Layers. The main objective of the project was to develop nondestructive testing (NDT) techniques capable of detecting and quantifying delaminations in HMA pavements. The NDT techniques should be applicable to construction, project design, and network-level assessments.

During Phase 1 of the project, the research team evaluated NDT methods that could potentially detect the most typical delaminations in asphalt pavements. Both laboratory and field testing were conducted during this task. Based on the findings from this testing, the manufacturers of two promising technologies conducted further development of their products to meet the goals of this project in Phase 2. The two technologies advanced in this research were ground-penetrating radar (GPR) and impact echo/spectral analysis of surface waves (IE/SASW).

Additionally, the project developed guidelines and piloted both NDT technologies in collaboration with highway agencies. Once completed, the results from this additional scope of work will be published as an addendum to this report.

CONTENTS

CHAPTER 1

3d-Radar Ground-Penetrating Radar Field Testing Results for Locating Cores—Florida

The research in this volume was developed by the research team as listed on the title page. It was lead by Dr. Nam Tran.

Field testing of the 3d-Radar ground-penetrating radar (GPR) system was carried out at sites in Florida, Kansas, and Maine. The equipment configuration used for this testing is shown in Figure 1.1. The data were collected at 3 nominal speeds: 40 mph, 20 mph, and 5 mph, and the level of detail of the data increased as the speed was lowered. The data analysis was carried out on the lowest-speed data, because these data had the highest level of detail. This data collection was carried out on a smaller section of pavement that was selected to most likely include delaminations. The selection of the test area was based on a review of the higher-speed data, on observation of surface distress, and on core data available from previous testing conducted by the corresponding state department of transportation.

The primary purpose of the initial review of the GPR data was to identify a 2,000-ft-long section for testing of the mechanical wave system. An additional objective was to identify specific locations for coring, which was carried out in conjunction with the mechanical wave testing. Mechanical wave testing was carried out only in Florida and Kansas, so those sites were reviewed.

The section selected for a more detailed analysis was based on a review of the three-dimensional (3-D) GPR data and on the observed surface conditions. The focus was on the southbound section, particularly the segment between Milepost (MP) 413 and the southbound rest area entrance. Surface distress observed in this area suggests some moisture damage in the layers below. See Figure 1.2.

Core data in this area show a total asphalt thickness of approximately 9 in. In 1997, the pavement was milled approximately 5 in. and replaced with a 1-in. friction course, a 1.5-in.-thick layer of 12.5 mm mix, a 1.5-in.-thick layer of 19 mm mix, and a 0.5-in. layer of asphalt rubber membrane interlayer (ARMI). It is believed, on the basis of core data, that moisture damage was occurring either between the 12-mm and the 19-mm mixes or between the 19-mm mix and the ARMI layer.

Figure 1.3 shows an overview of the GPR layer structure data for this southbound region. The section is fairly homogeneous, but it appears that the overall asphalt thickness is lower in the segment north of the rest area. Figure 1.4 shows local detail of the pavement cross section. Note that what appears to be the ARMI layer is evident periodically in the GPR data structure. It is possible that if this layer is impermeable, a layer boundary will appear in the GPR data where moisture has been retained. On the basis of a qualitative review of the depth slice data, it was recommended that the mechanical wave testing be carried out on a 2,000-ft-long section that began 2,000 ft south of MP 413.

Table 1.1 is a summary of the field observations and selected core locations. The surface reference marks are used to tie the location of test data files to physical observations of distress or other features on the surface of the pavement.

Figures 1.5, 1.6, 1.7 and 1.8 show the core locations superimposed on the GPR horizontal slice and profile data. The top figure is the horizontal (depth) slice, the bottom left figure is the longitudinal profile, and the bottom right figure is the transverse profile. The numbers in circles are the core numbers. Figure 1.9 shows the automated activity analysis for the Gainesville site. The likelihood of distress is color coded. The location of each core was added to the analysis.

Table 1.2 is the summary log of GPR images corresponding to the surface reference marks and sites identified as potential core locations. The table includes the references to Figures 1.10 through 1.20 where the GPR images are located.

Figure 1.1. 3d-Radar equipment used for field tests.

Figure 1.2. Pavement conditions between MP 413 and rest area.

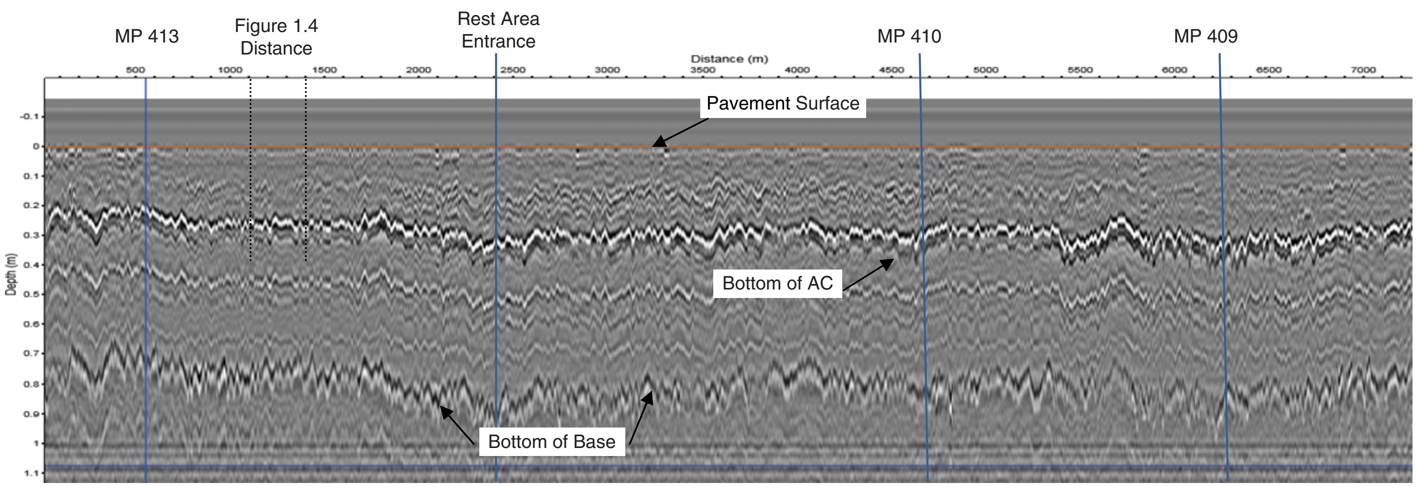


Figure 1.3. Overview of 20-mph GPR data for I-75 southbound (centerline).

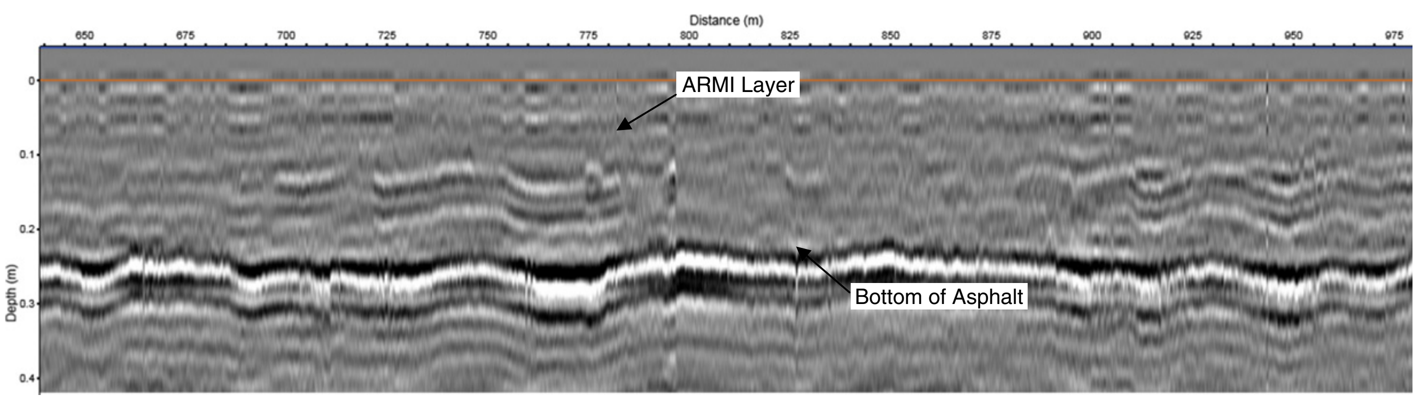


Figure 1.4. Local detail of layer structure from 5-mph GPR data (MP 413 at 112 m).

Table 1.1. Pavement References and Core Locations at I-75 Southbound Test Section

Description of Surface Reference Mark	File Distance (m)	Distance from MP 413 (ft)	Offset
MP 413	111.65	0	na
Hole	139.25	91	Centerline
Unknown	156.00	146	Full width
Crack	381.25	885	RWP to LWP
Crack	386.00	900	RWP to LWP
Hole	712.77	1,972	Left of centerline
Crack	717.50	1,988	Full width, at small angle
Start of test	721.25	2,000	na
Crack	901.50	2,591	Full width
Crack	903.25	2,597	Full width
Crack	905.20	2,604	Full width
Hole	943.40	2,729	RWP
Traffic loop and cores	1,317.40	3,956	Centerline
Core locations			
1	792.0	2,232	RWP
2	795.0	2,242	RWP
3	798.0	2,252	RWP
4	1,211.0	3,607	RWP
5	1,218.7	3,632	RWP
6	1,221.0	3,640	RWP
7	1,252.1	3,742	RWP
8	1,253.0	3,745	RWP
9	1,413.0	4,270	RWP
10	1,418.0	4,286	RWP

Note: LWP = left wheelpath; RWP = right wheelpath; and na = not applicable. Data used in this table are taken from GPR File 12-5 (No. 12 at 5 mph).

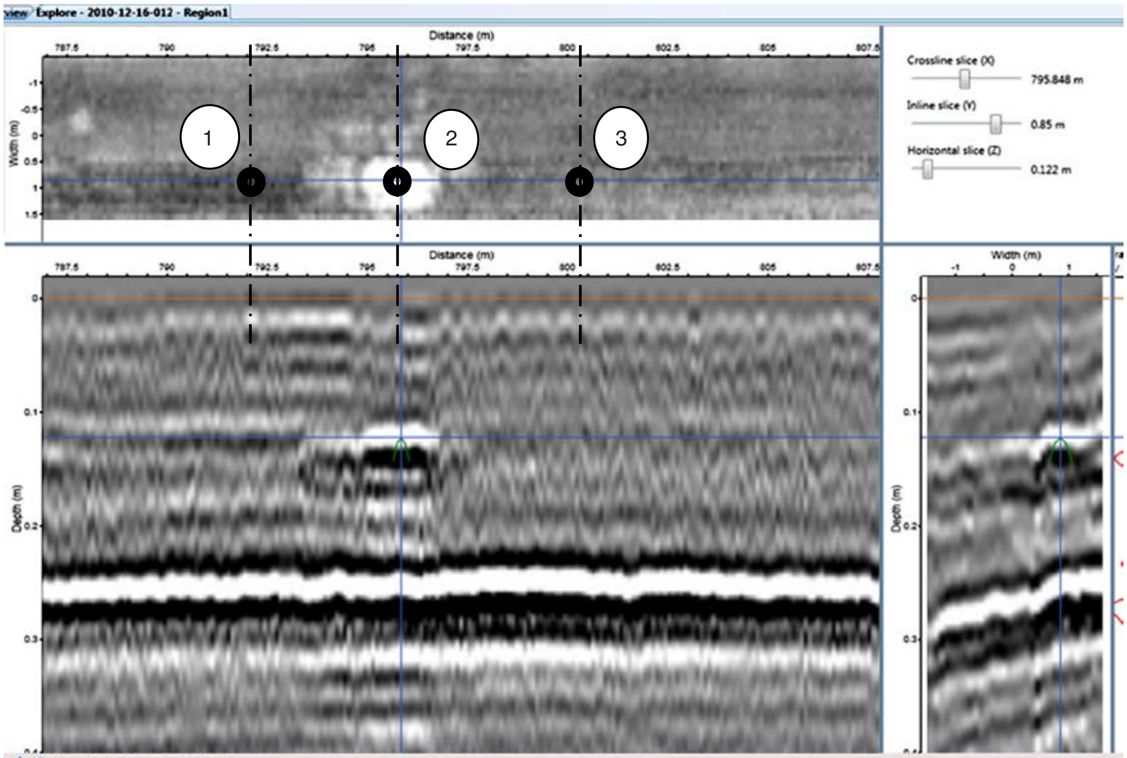


Figure 1.5. Core locations 1, 2, and 3.

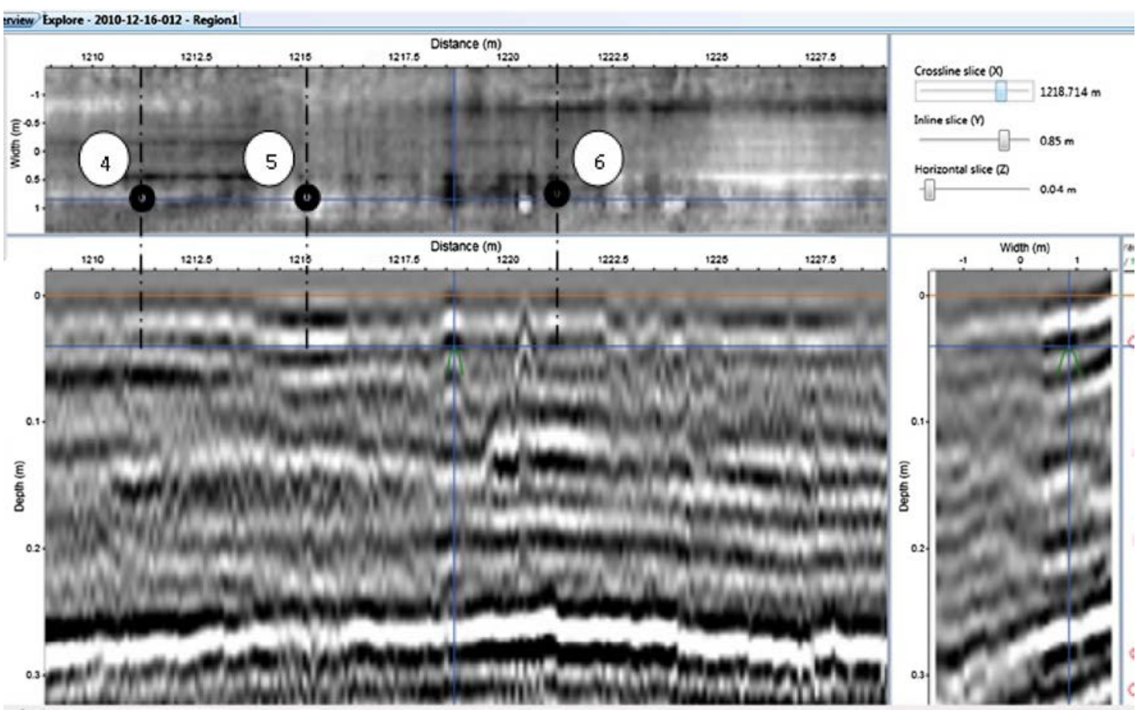


Figure 1.6. Core locations 4, 5, and 6.

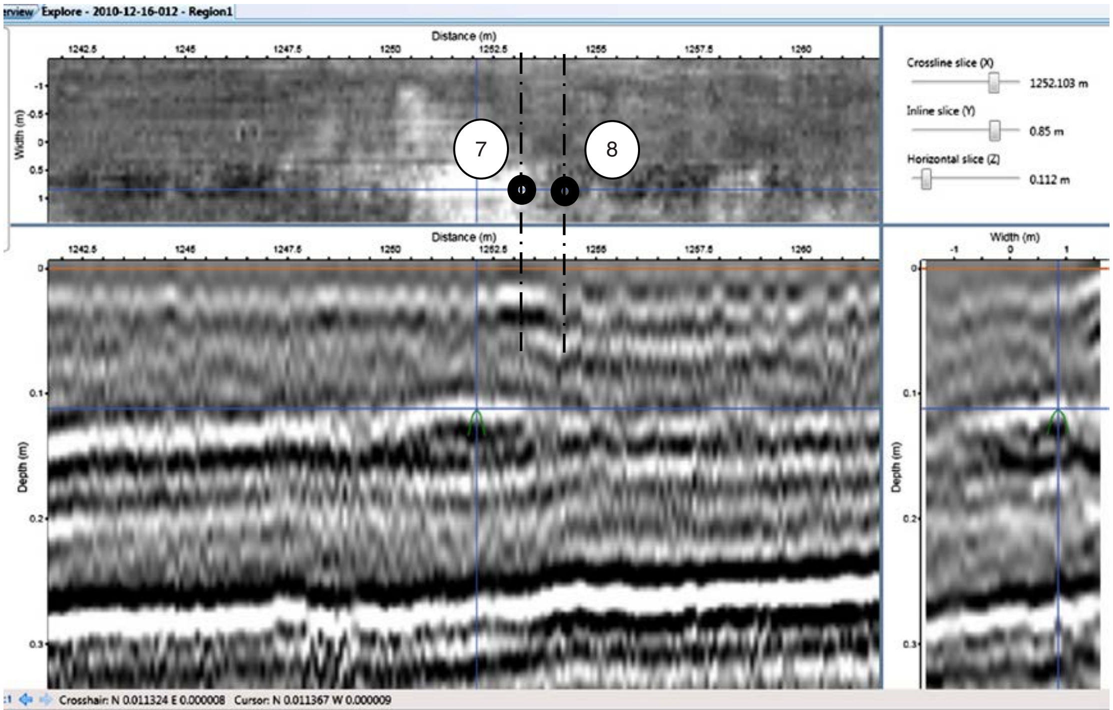


Figure 1.7. Core locations 7 and 8.

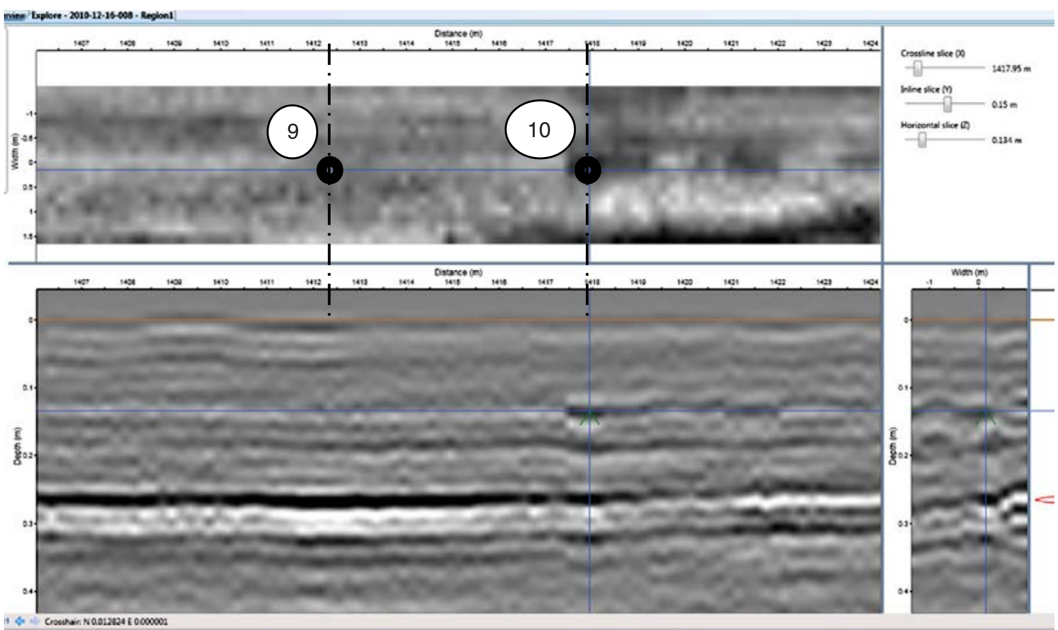


Figure 1.8. Core locations 9 and 10.

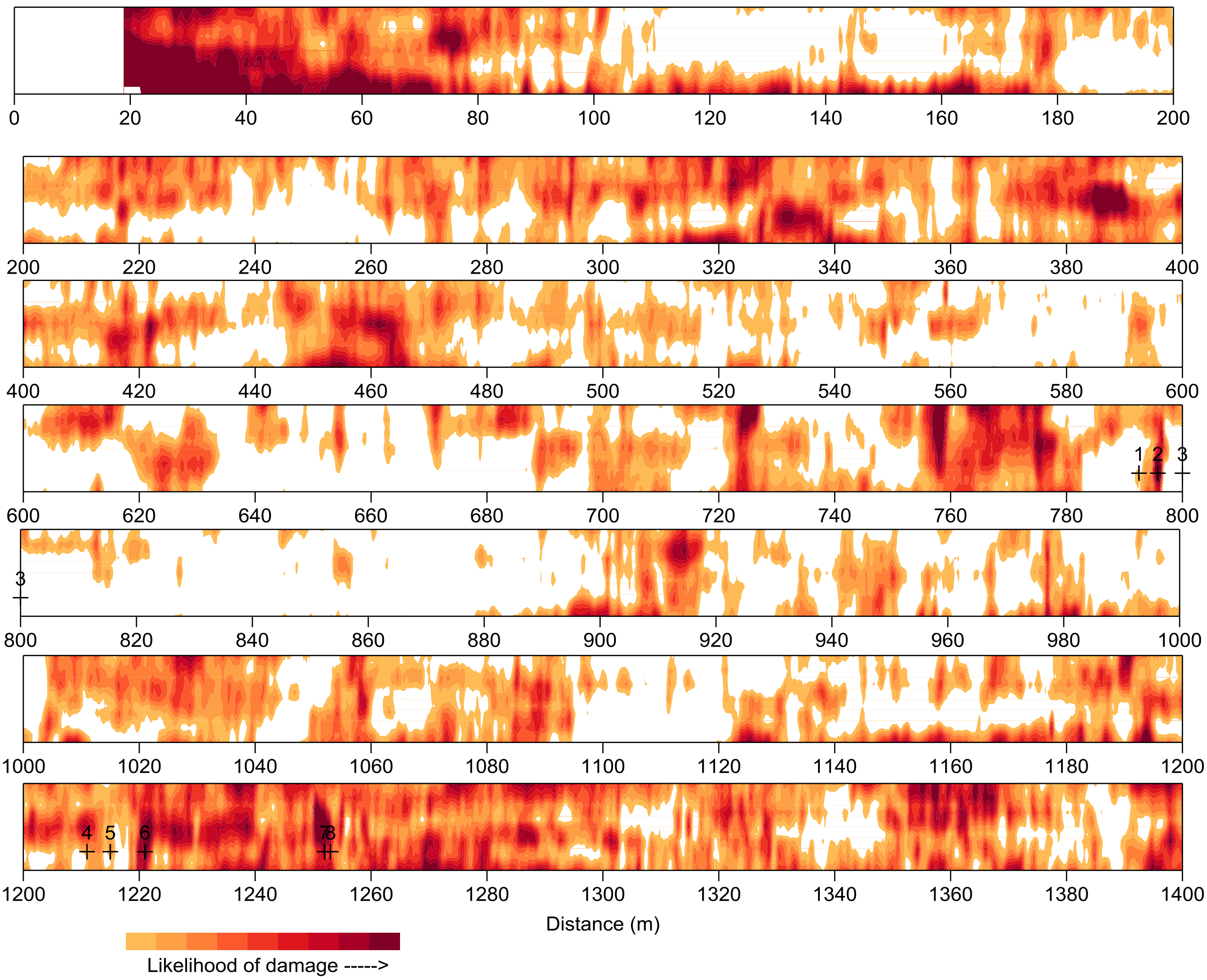


Figure 1.9. Automated activity analysis of Gainesville, Florida, site with core locations shown.

Table 1.2. GPR Surface Image Log

Description of Surface Reference Mark	File Distance (m)	Distance from MP 413 (ft)	Offset	Figure
MP 413	111.65	0	na	
Hole	139.25	91	Centerline	1.10
Unknown	156.00	146	Full width	1.11
Crack	381.25	885	RWP to LWP	1.12
Crack	386.00	900	RWP to LWP	1.12
Hole	712.77	1,972	Left of centerline	1.13
Crack	717.50	1,988	Full width, at small angle	1.13
Start of test	721.25	2,000	na	
Crack	901.50	2,591	Full width	1.14
Crack	903.25	2,597	Full width	1.14
Crack	905.20	2,604	Full width	1.14
Hole	943.40	2,729	RWP	1.15
Traffic loop and cores	1,317.40	3,956	Centerline	1.16
Potential core locations				
Anomaly at 12-cm depth	795.0	2,242	RWP	1.17
Anomalies at 4-cm depth	1,218.7	3,632	RWP	1.18
Anomaly at 11-cm depth	1,252.1	3,742	RWP	1.19
Anomaly at 13-cm depth	File 8, 20 mph	2,837	Centerline	1.20

Note: na = not applicable. Data used in this table are taken from GPR File 12-5 (No. 12 at 5 mph).

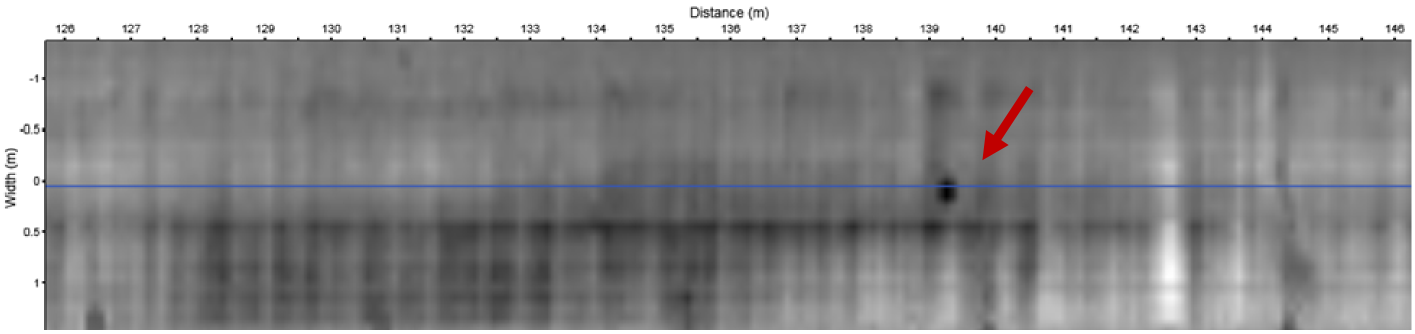


Figure 1.10. Hole (red arrow) ***at file distance 139.25 m.***

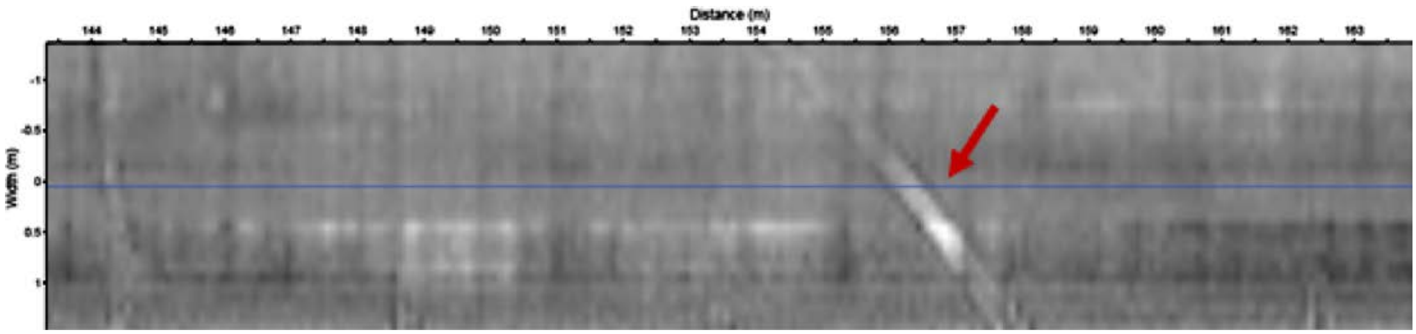


Figure 1.11. Unknown mark (red arrow) ***at file distance 156.00 m.***

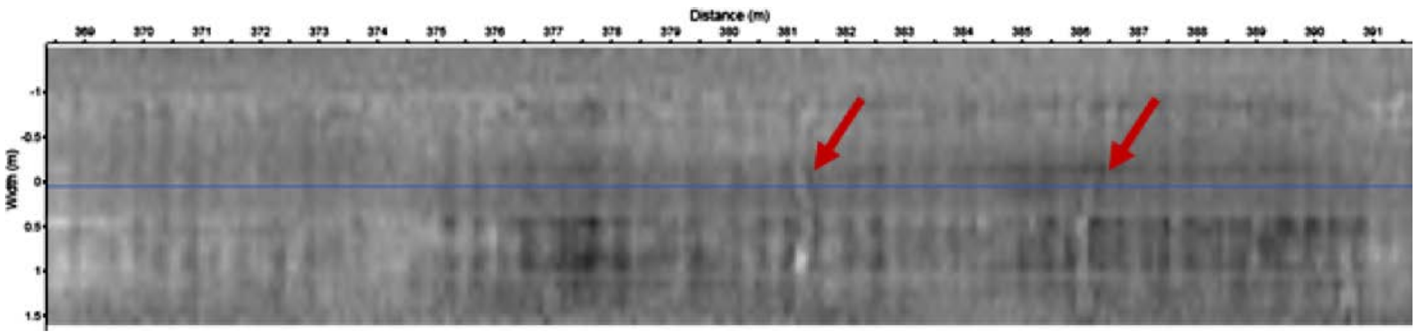


Figure 1.12. Crack (left red arrow) ***at file distance 381.25 m (885 ft from MP 413) and 386.00 m.***

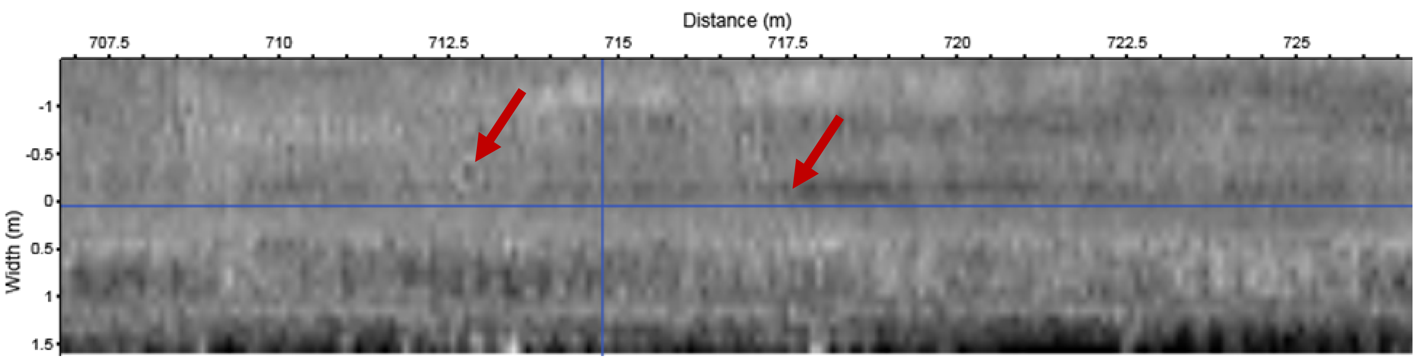


Figure 1.13. Hole (left red arrow) ***at file distance 712.77 m and crack*** (right red arrow) ***at file distance 717.50 m.***

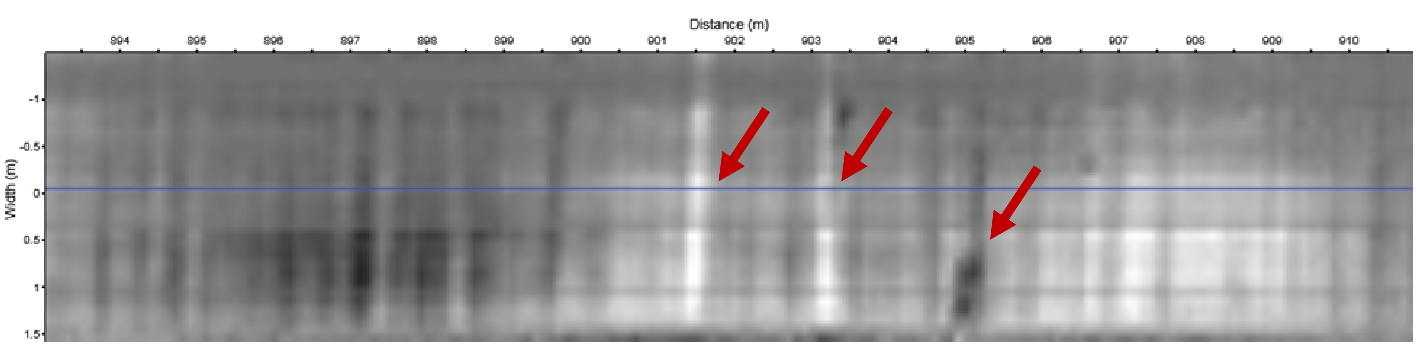


Figure 1.14. Crack (left red arrow) ***at file distance 901.50 m, 903.25 m, and 905.20 m.***

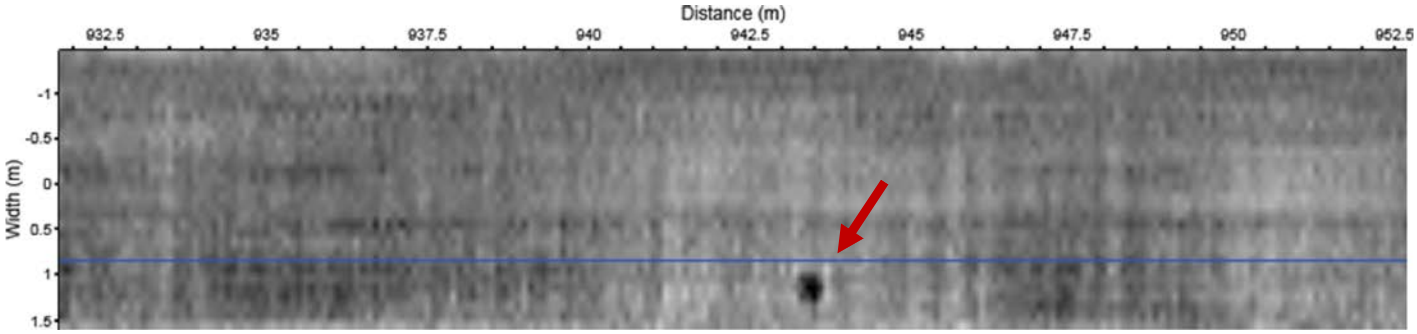


Figure 1.15. Hole **(red arrow)** ***at file distance 943.40 m.***

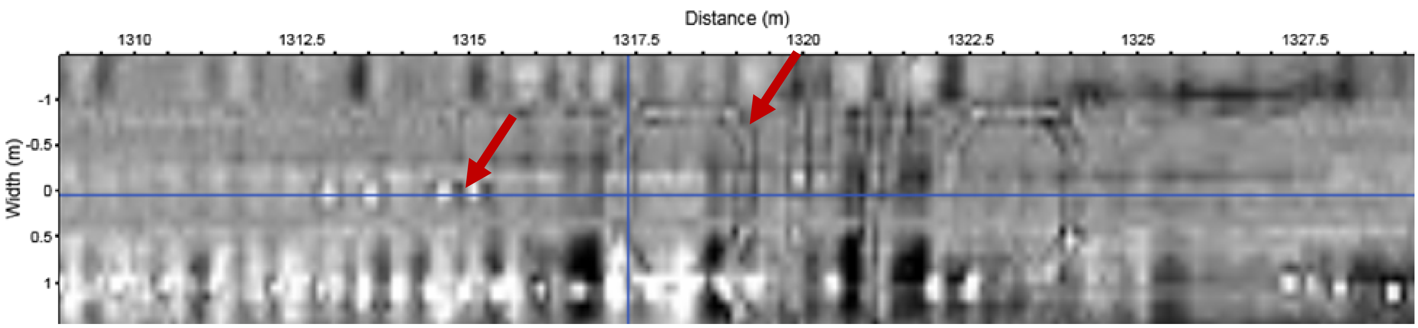


Figure 1.16. Traffic loop **(right arrow)** ***and cores*** **(left arrow)** ***at file distance 1,317.40 m.***

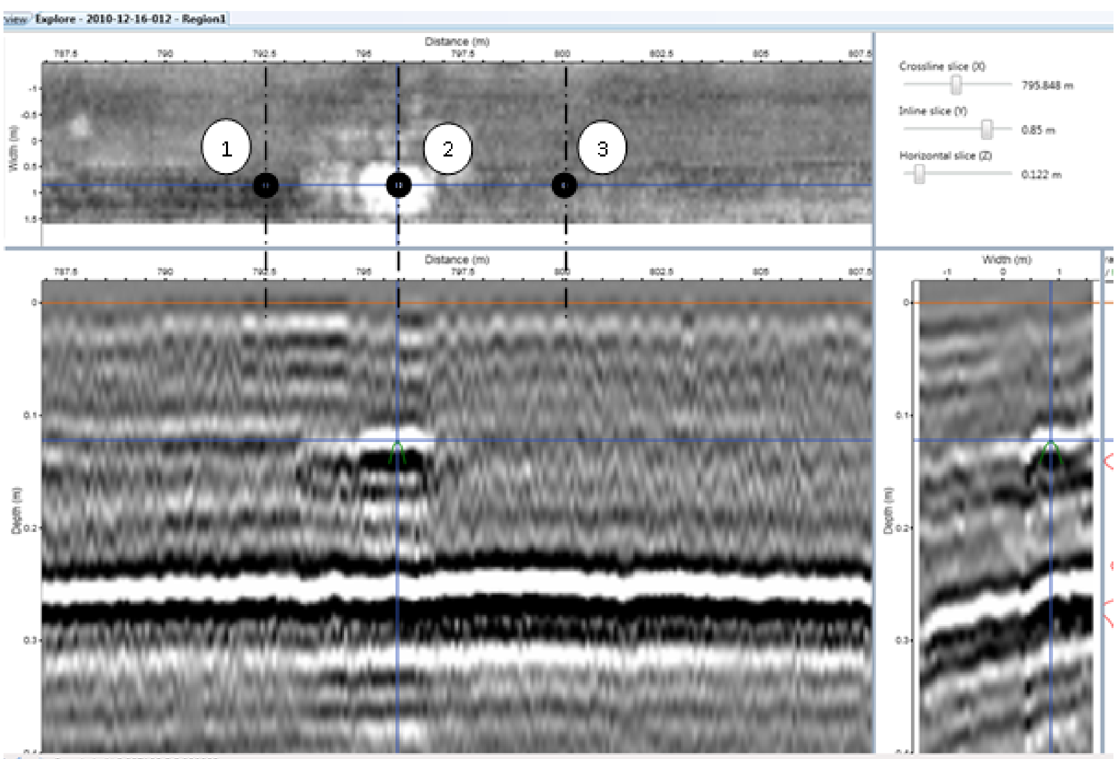


Figure 1.17. Anomaly at 12-cm depth, file distance 795.0 m.

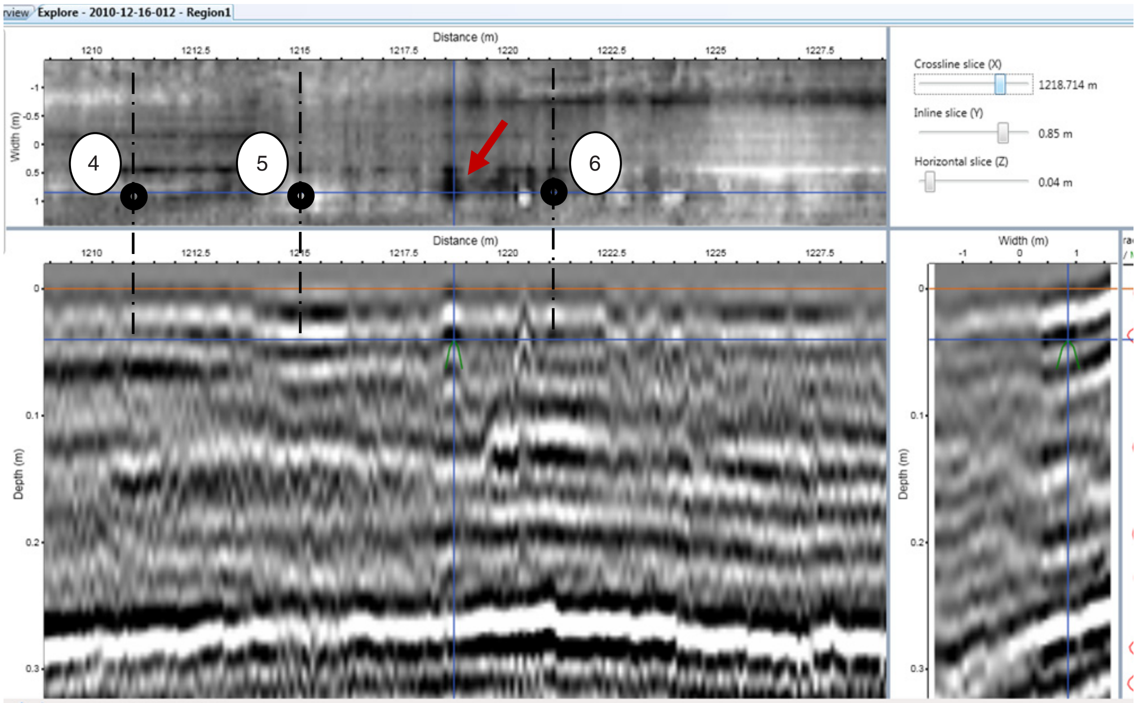


Figure 1.18. Anomalies at 4-cm depth, file distance 1,218.7 m.

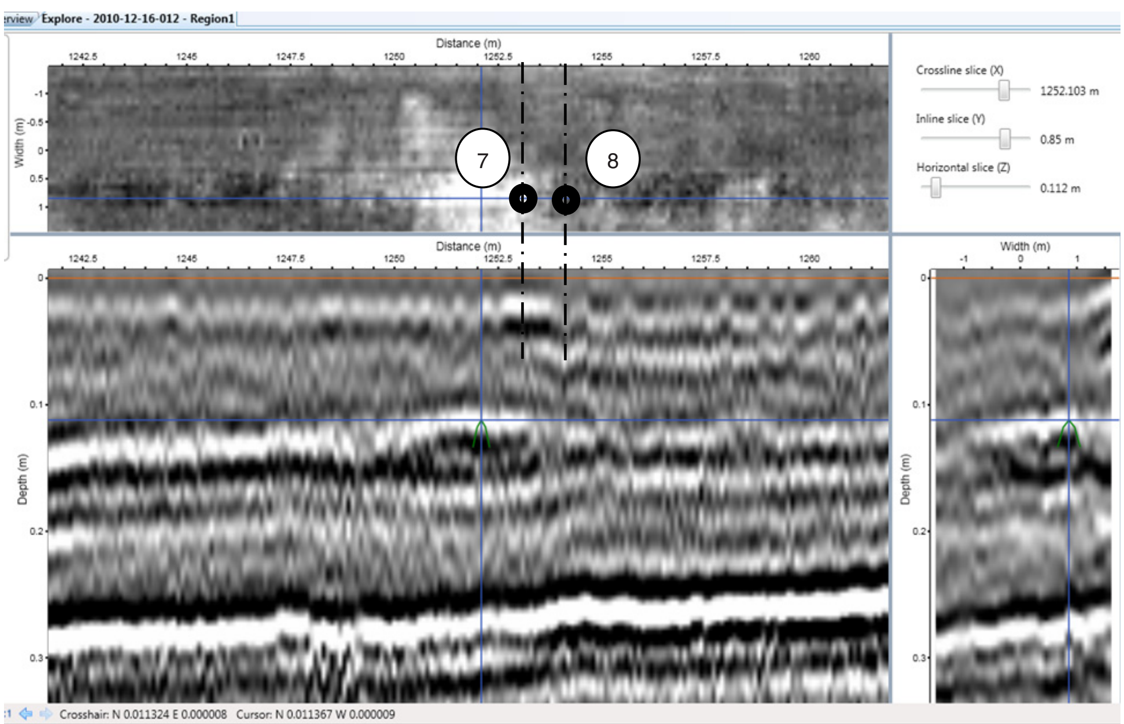


Figure 1.19. Anomaly at 11-cm depth, file distance 1,252.1 m.

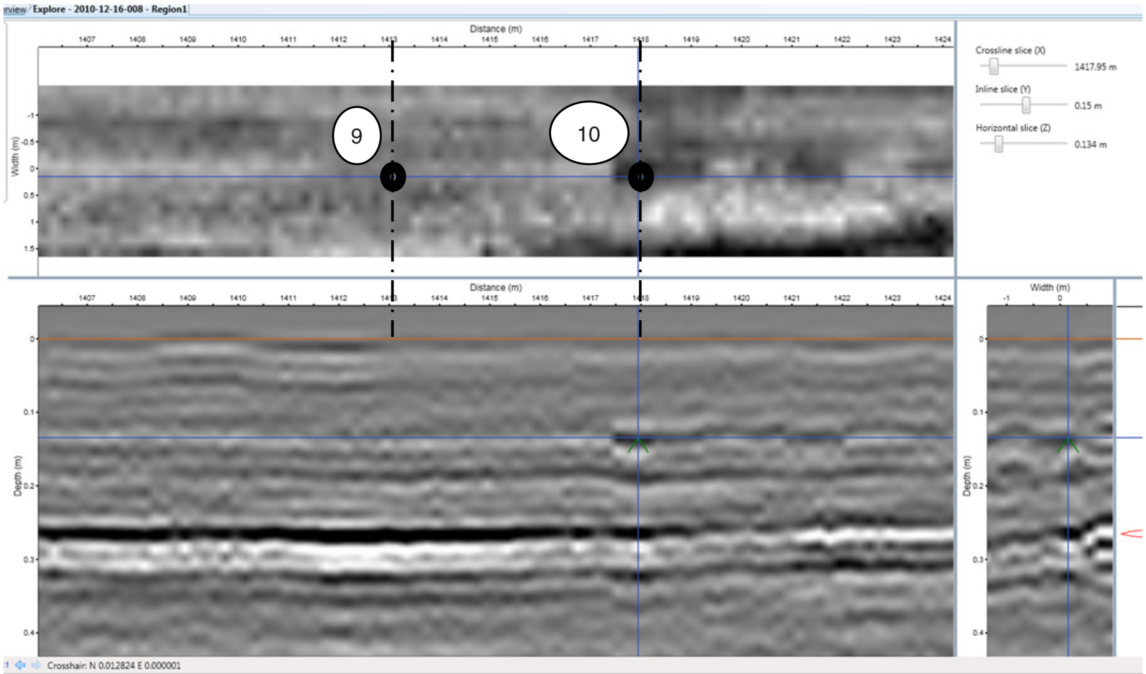


Figure 1.20. Anomaly at 13-cm depth, File 8, 20 mph.

CHAPTER 2

Florida Cores Analysis: Coring Locations and Results for I-75 Pavement Site

Pavement sections with some delamination problems in four states were selected for uncontrolled field testing of the two nondestructive testing (NDT) techniques. However, because of some delays in equipment improvement, uncontrolled field testing did not begin until winter 2010 for the ground-penetrating radar (GPR) technique and until spring 2011 for the mechanical wave technique. Weather conditions were not suitable for field testing in Maine and Washington State. Therefore, the two NDT techniques were evaluated only on pavement sections in Florida and Kansas. This chapter discusses the selection of coring locations and the results from testing cores in the laboratory.

In Florida, pavement sections selected for high-speed GPR testing were northbound and southbound segments between MP 413 and MP 409 on I-75. After the high-speed GPR testing was completed, results were reviewed, and an approximately 4,500-ft southbound section starting from MP 413 was selected for low-speed GPR testing. Core data in this area provided by the Florida Department of Transportation (FDOT) showed a total asphalt thickness of approximately 9 in. In 1996, the pavement was milled approximately 5.5 in. and replaced with a 0.5-in. layer of asphalt rubber membrane interlayer (ARMI), a 2-in. layer of 19-mm Superpave mix, a 1.25-in. layer of 12.5-mm Superpave mix, and a 0.75-in. layer of open-graded friction course (OGFC). Based on results of indirect tensile strength testing of field cores, moisture damage may be occurring either between the 12-mm mix and the 19-mm mix or between the 19-mm mix and the interlayer layer.

After reviewing results of the GPR testing and other information provided by FDOT, the research team decided to conduct field testing of the mechanical wave technique on the same 2,000-ft section starting from MP 413. In addition, locations where anomalies were identified in the GPR results were selected for lightweight deflectometer testing and cutting cores to verify the pavement condition. More details on the core locations are in Chapter 1.

Table 2.1 shows the locations where anomalies were found in the GPR results and where cores were extracted in the 4,600-ft pavement site starting from MP 413. Chapter 1 showed the anomalies and the locations of the 10 cores in conjunction with the NDT test results.

All the cores were intact and brought back to the NCAT laboratory for testing. Results of laboratory testing according to AASHTO T 283 test method are shown in Tables 2.2 through 2.6. However, the mix placed in the bottom of Layer 2 showed signs of stripping (visually ranked as No. 4 on the basis of AASHTO T 283).

Table 2.1. Locations of Anomalies and Cores for I-75 Pavement Site

Core No.	Distance (ft) from MP 413	Offset	GPR Observation
1	2,232	RWP	No anomaly
2	2,242	RWP	Anomaly
3	2,252	RWP	No anomaly
4	3,607	RWP	No anomaly
5	3,632	RWP	Anomaly
6	3,640	RWP	Anomaly
7	3,742	RWP	Anomaly
8	3,745	RWP	Anomaly
9	4,270	CL	No anomaly
10	4,286	CL	Anomaly

Note: CL = centerline.

Table 2.2. Testing Results for Layer 1 (OGFC)

Mix ID	Core ID	T166 (G_{mb})	% Water Absorbed	Corelok (G_{mb})	Reported (G_{mb})	Average Diameter (in.)	Average Height (in.)	Fail Load (lb)	Tensile Strength (psi)	Strip Rank
Lift 1	1	NA	NA	1.930	1.930	3.989	0.791	900.0	181.5	3
Lift 1	2	NA	NA	1.911	1.911	3.984	0.911	825.0	144.8	3
Lift 1	3	NA	NA	1.928	1.928	3.995	0.887	650.0	116.7	2
Lift 1	4	NA	NA	1.970	1.970	3.968	0.770	675.0	140.7	3
Lift 1	5	NA	NA	1.912	1.912	3.946	0.882	712.5	130.3	3
Lift 1	6	NA	NA	1.937	1.937	3.966	0.988	812.5	132.0	3
Lift 1	7	NA	NA	1.910	1.910	3.936	1.096	1,075.0	158.7	3
Lift 1	8	NA	NA	1.938	1.938	3.961	0.907	850.0	150.6	4
Lift 1	9	NA	NA	Broke	NA	3.979	0.599	NA	NA	NA
Lift 1	10	NA	NA	1.890	1.890	3.973	0.767	250.0	52.2	4
Average	na	na	na	1.925	1.925	3.970	0.860	750.000	134.2	na
SD	na	na	na	0.023	0.023	0.019	0.137	227.675	35.9	na

Note: OGFC = open-graded friction course; na = not applicable; NA = not available; and SD = standard deviation.

Table 2.3. Testing Results for Layer 2 (Dense-Graded Mix)

Mix ID	Core ID	T166 (G_{mb})	% Water Absorbed	Corelok (G_{mb})	Reported (G_{mb})	Average Diameter (in.)	Average Height (in.)	Fail Load (lb)	Tensile Strength (psi)	Strip Rank
Lift 2	1	2.352	0.9	NA	2.352	3.989	2.056	1,725.0	133.9	4
Lift 2	2	2.403	0.5	NA	2.403	3.984	2.104	1,550.0	117.7	4
Lift 2	3	2.371	0.4	NA	2.371	3.995	2.142	1,750.0	130.2	4
Lift 2	4	2.357	1.2	NA	2.357	3.968	2.309	1,400.0	97.3	4
Lift 2	5	2.310	1.5	NA	2.310	3.946	2.094	1,550.0	119.4	4
Lift 2	6	2.319	4.1	2.301	2.301	3.966	1.675	1,100.0	105.4	4
Lift 2	7	2.359	0.3	NA	2.359	3.936	1.681	1,425.0	137.1	4
Lift 2	8	2.359	0.9	NA	2.359	3.961	1.726	1,425.0	132.7	4
Lift 2	9	2.355	1.1	NA	2.355	3.979	2.299	1,900.0	132.2	4
Lift 2	10	2.356	0.6	NA	2.356	3.973	2.400	1,925.0	128.5	4
Average	na	2.354	1.2	na	2.352	3.970	2.049	1,575.0	123.4	na
SD	na	0.026	1.1	na	0.029	0.019	0.268	254.7	13.3	na

Note: na = not applicable; NA = not available.

Table 2.4. Testing Results for Layer 3 (ARMI)

Mix ID	Core ID	T166 (G_{mb})	% Water Absorbed	Corelok (G_{mb})	Reported (G_{mb})	Average Diameter (in.)	Average Height (in.)	Fail Load (lb)	Tensile Strength (psi)	Strip Rank
Lift 3	1	2.165	1.1	NA	2.165	3.989	0.812	250.0	49.1	1
Lift 3	2	2.174	2.7	2.199	2.199	3.984	0.629	300.0	76.2	4
Lift 3	3	2.169	1.4	NA	2.169	3.995	0.560	200.0	56.9	1
Lift 3	4	2.156	2.3	2.202	2.202	3.968	0.570	150.0	42.2	4
Lift 3	5	2.045	3.3	2.087	2.087	3.946	0.499	100.0	32.3	3
Lift 3	6	2.064	1.4	NA	2.064	3.966	0.444	100.0	36.2	1
Lift 3	7	2.068	2.4	2.096	2.096	3.936	0.780	300.0	62.2	4
Lift 3	8	2.078	1.7	NA	2.078	3.961	0.891	350.0	63.1	4
Lift 3	9	2.269	0.5	NA	2.269	3.979	0.572	275.0	77.0	1
Lift 3	10	2.218	0.9	NA	2.218	3.973	0.572	250.0	70.0	1
Average	na	2.141	1.8	NA	2.155	3.970	0.633	227.5	56.5	na
SD	na	0.074	0.9	NA	0.070	0.019	0.146	87.0	16.1	na

Note: ARMI = asphalt rubber membrane interlayer; na = not applicable; NA = not available.

Table 2.5. Testing Results for Layer 4 (Dense-Graded Mix)

Mix ID	Core ID	T166 (G_{mb})	% Water Absorbed	Corelok (G_{mb})	Reported (G_{mb})	Average Diameter (in.)	Average Height (in.)	Fail Load (lb)	Tensile Strength (psi)	Strip Rank
Lift 4	1	2.313	0.6	NA	2.313	3.989	1.359	1,450.0	170.3	1
Lift 4	2	2.222	1.4	NA	2.222	3.984	1.132	1,050.0	148.2	2
Lift 4	3	2.256	1.2	NA	2.256	3.995	0.918	1,025.0	177.9	1
Lift 4	4	2.241	0.8	NA	2.241	3.968	1.459	1,050.0	115.4	1
Lift 4	5	2.234	1.1	NA	2.234	3.946	0.872	600.0	111.0	1
Lift 4	6	2.260	0.3	NA	2.260	3.966	1.420	1,150.0	130.0	1
Lift 4	7	2.306	0.4	NA	2.306	3.936	1.631	1,575.0	156.2	2
Lift 4	8	2.304	0.6	NA	2.304	3.961	1.715	1,300.0	121.8	2
Lift 4	9	2.294	0.6	NA	2.294	3.979	0.782	800.0	163.7	1
Lift 4	10	2.334	0.4	NA	2.334	3.973	0.577	450.0	125.0	1
Average	na	2.276	0.8	NA	2.276	3.970	1.187	1,045.0	141.9	na
SD	na	0.039	0.4	NA	0.039	0.019	0.387	354.9	24.3	na

Note: na = not applicable; NA = not available.

Table 2.6. Testing Results for Layer 4 (Dense-Graded Mix)

Mix ID	Core ID	T166 (G_{mb})	% Water Absorbed	Corelok (G_{mb})	Reported (G_{mb})	Average Diameter (in.)	Average Height (in.)	Fail Load (lb)	Tensile Strength (psi)	Strip Rank
Lift 5	1	2.300	1.4	NA	2.300	3.989	1.681	1,400.0	132.9	1
Lift 5	2	2.196	2.8	2.180	2.180	3.984	1.971	1,550.0	125.7	1
Lift 5	3	2.279	0.9	NA	2.279	3.995	2.213	1,900.0	136.8	1
Lift 5	4	2.254	1.6	NA	2.254	3.968	2.086	1,475.0	113.4	2
Lift 5	5	2.282	0.9	NA	2.282	3.946	2.429	1,600.0	106.3	2
Lift 5	6	2.251	1.3	NA	2.251	3.966	2.268	1,425.0	100.8	2
Lift 5	7	2.327	1.3	NA	2.327	3.936	1.584	1,300.0	132.7	2
Lift 5	8	2.301	1.3	NA	2.301	3.961	1.878	1,550.0	132.7	1
Lift 5	9	2.246	0.4	NA	2.246	3.979	1.716	1,775.0	165.5	1
Lift 5	10	2.229	0.5	NA	2.229	3.973	1.517	1,675.0	176.9	1
Average	na	2.267	1.2	NA	2.265	3.970	1.934	1,565.0	132.4	na
SD	na	0.039	0.7	NA	0.042	0.019	0.311	181.1	24.0	na

Note: na = not applicable; NA = not available.

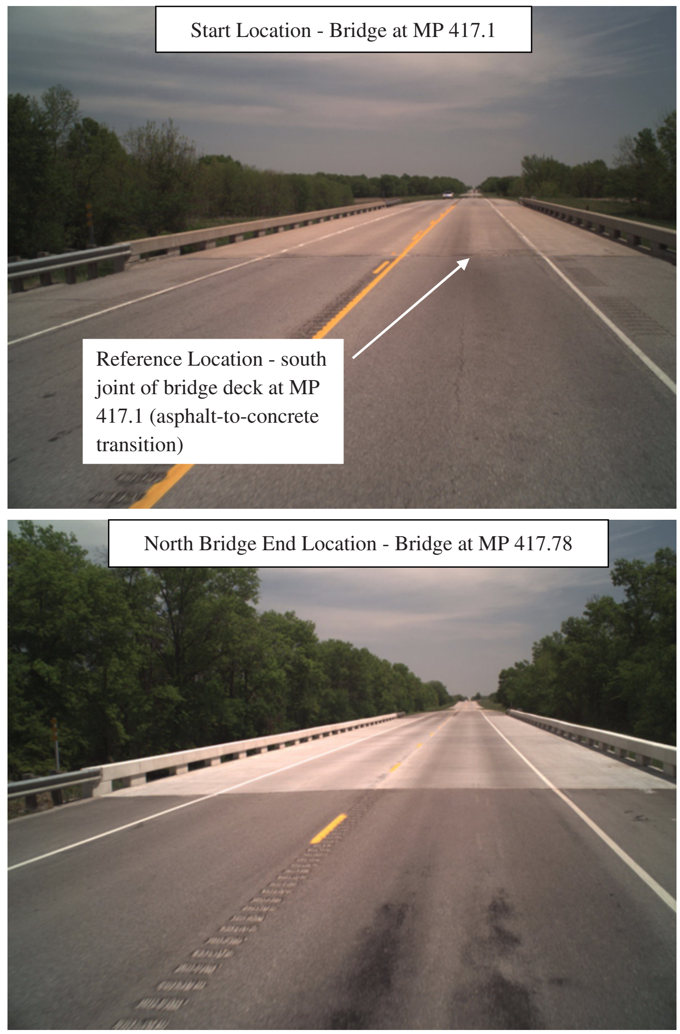
CHAPTER 3

3d-Radar Ground-Penetrating Radar Field Testing Results for Locating Cores—Kansas

Field testing of the 3d-Radar ground-penetrating radar (GPR) system was carried out at sites in Florida, Kansas, and Maine. The equipment configuration used for this testing is shown in Figure 3.1. The data were collected at 3 nominal speeds: 40 mph, 20 mph, and 5 mph. The level of detail of the data increased as the speed was lowered. The data analysis was carried out on the lowest-speed data, because these data had the highest level of detail. This data collection was carried out on a smaller section of pavement that was selected to most likely include delaminations. The selection of the test area was based on a review of the higher-speed data, on observation of surface distress, and on core data available from previous testing conducted by the corresponding state department of transportation.

The primary purpose of the initial review of the GPR data was to identify a 2,000-ft long section for testing of the mechanical wave system. Figure 3.2 gives the limits of the test section on US-400 in Kansas. An additional objective was to identify specific locations for coring, which was carried out in conjunction with the mechanical wave testing. Table 3.1 lists the location of the cores. Figures 3.3 through 3.6 provide GPR results related to the core locations.

Figure 3.1. 3d-Radar equipment used for field tests.



Note: MP = milepost.

Figure 3.2. Limits of test section for coring.

Table 3.1. Kansas US-400 Test Section and Core Locations

Location	KDOT Video Frame	GPR (m)	GPR (ft)	Distance from South Bridge Deck Joint (ft)	County MP	State MP	Offset	Depth (m)	Depth (in.)
Reference locations									
South Bridge Deck, south joint	7,579	171.48	562.5	0.0	4.992	417.097	na	na	na
Core 19	7,671	908.75	2,980.7	2,418.2	5.450	417.555	NB Between center of lane and LWP	Stripped and missing below 5.5 in.	
Pavement marker	7,678	970.53	3,183.3	2,620.9	5.488	417.593	LWP	na	na
North Bridge Deck, south joint	7,715	1,263.38	4,143.9	3,581.4	NA	NA	na	na	na
Suggested core locations									
1—GPR Anomaly	7,620	501.00	1,643.3	1,080.8	5.197	417.302	Centerline of lane	0.100	3.9
2—GPR Anomaly	7,643	688.00	2,256.6	1,694.2	5.313	417.418	RWP	0.138	5.4
3—GPR Anomaly	7,665	864.00	2,833.9	2,271.5	5.422	417.527	Centerline of lane	0.072	2.8
4—GPR Anomaly	7,692	1,085.00	3,558.8	2,996.3	5.559	417.664	RWP	0.117	4.6
5—GPR Anomaly	7,693	1,093.00	3,585.0	3,022.6	5.564	417.669	LWP	0.130	5.1
6—GPR Anomaly	7,701	1,154.60	3,787.1	3,224.6	5.603	417.708	RWP	0.081	3.2
7—Additional core	NA	259.50	851.3	288.8	5.047	417.152	Centerline of lane	na	na
8—Additional core	NA	302.00	990.4	427.9	5.073	517.178	Centerline of lane	na	na

Note: The shaded cells indicate the location of the core. KDOT = Kansas Department of Transportation; MP = milepost; LWP = left wheelpath; NB = northbound; RWP = right wheelpath; NA = not available; na = not applicable.

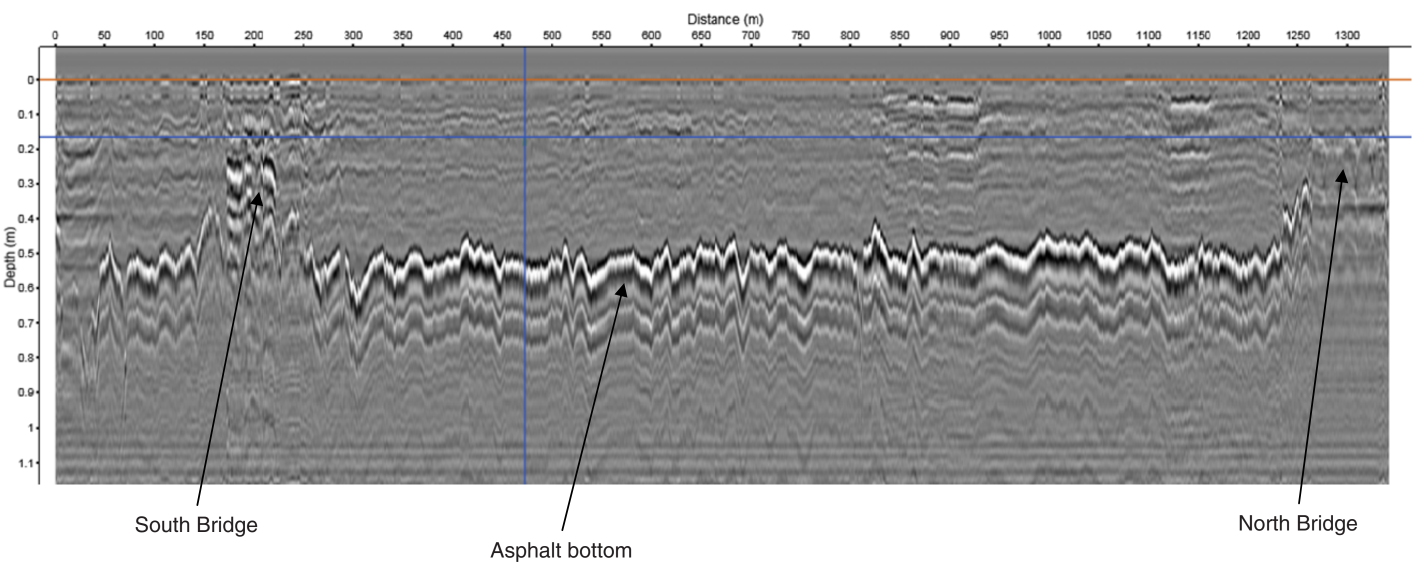


Figure 3.3. Centerline GPR data collected at 5 mph between MP 417 and MP 417.8.

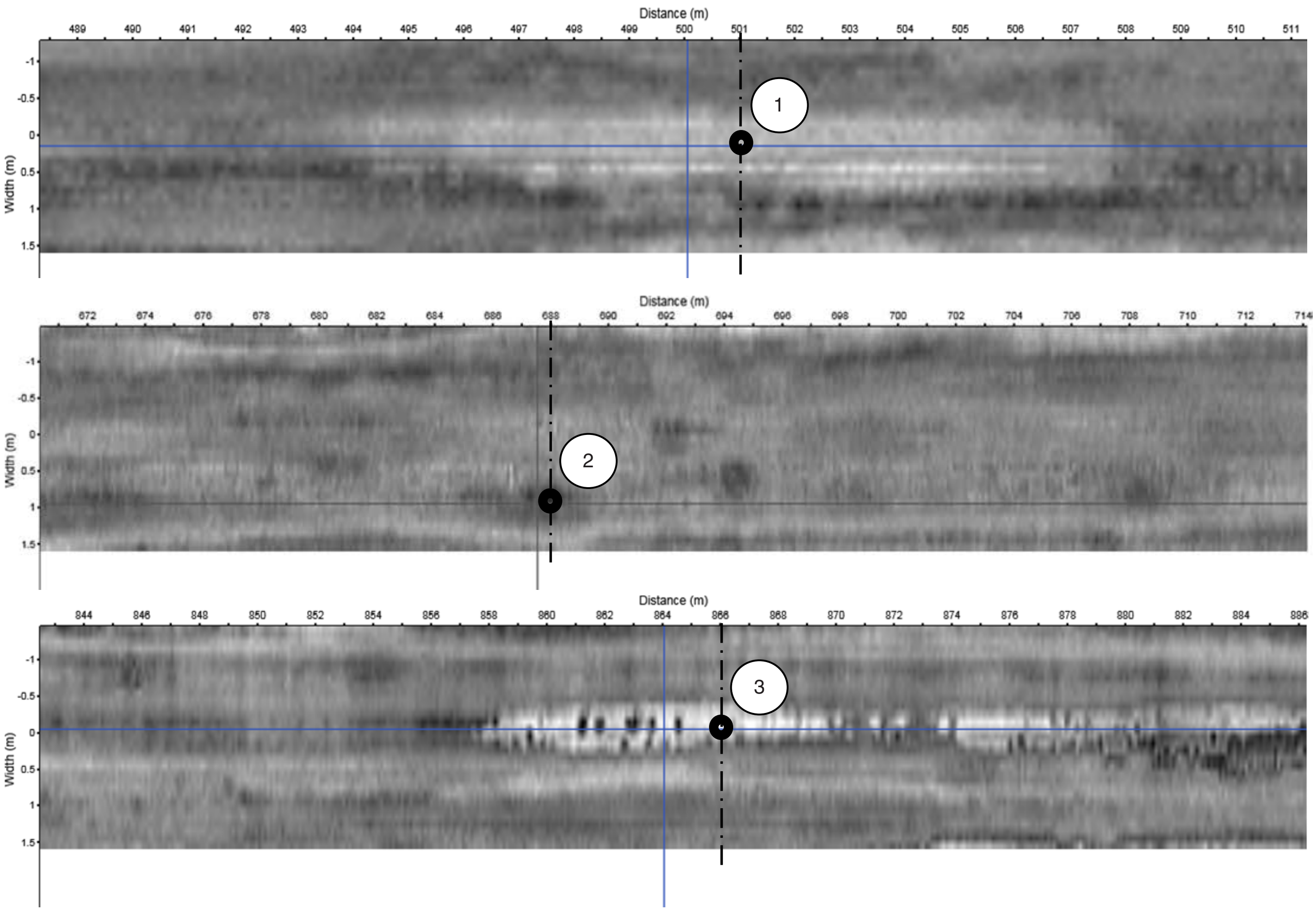


Figure 3.4. Sample GPR depth slice data at core locations 1 through 3.

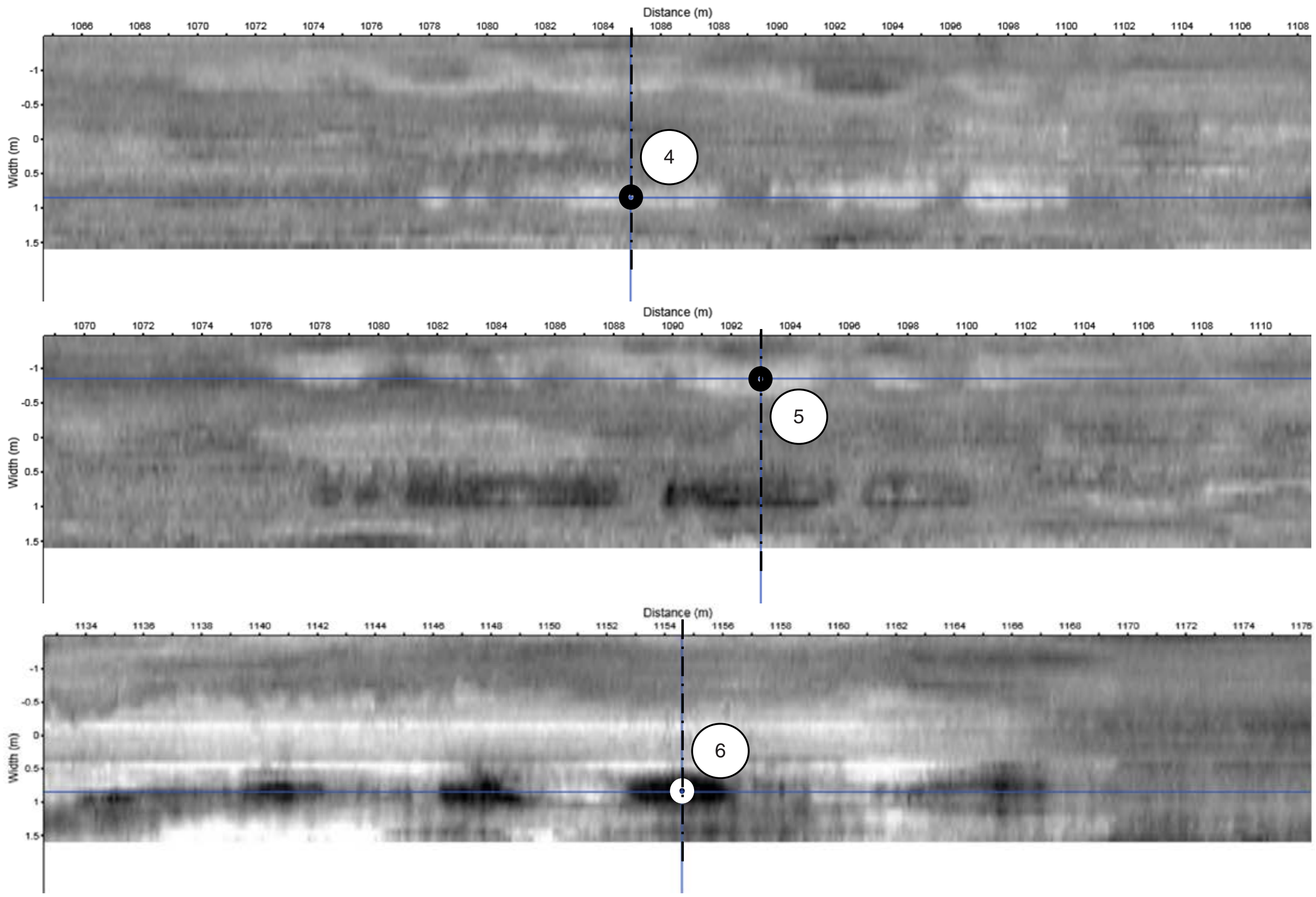
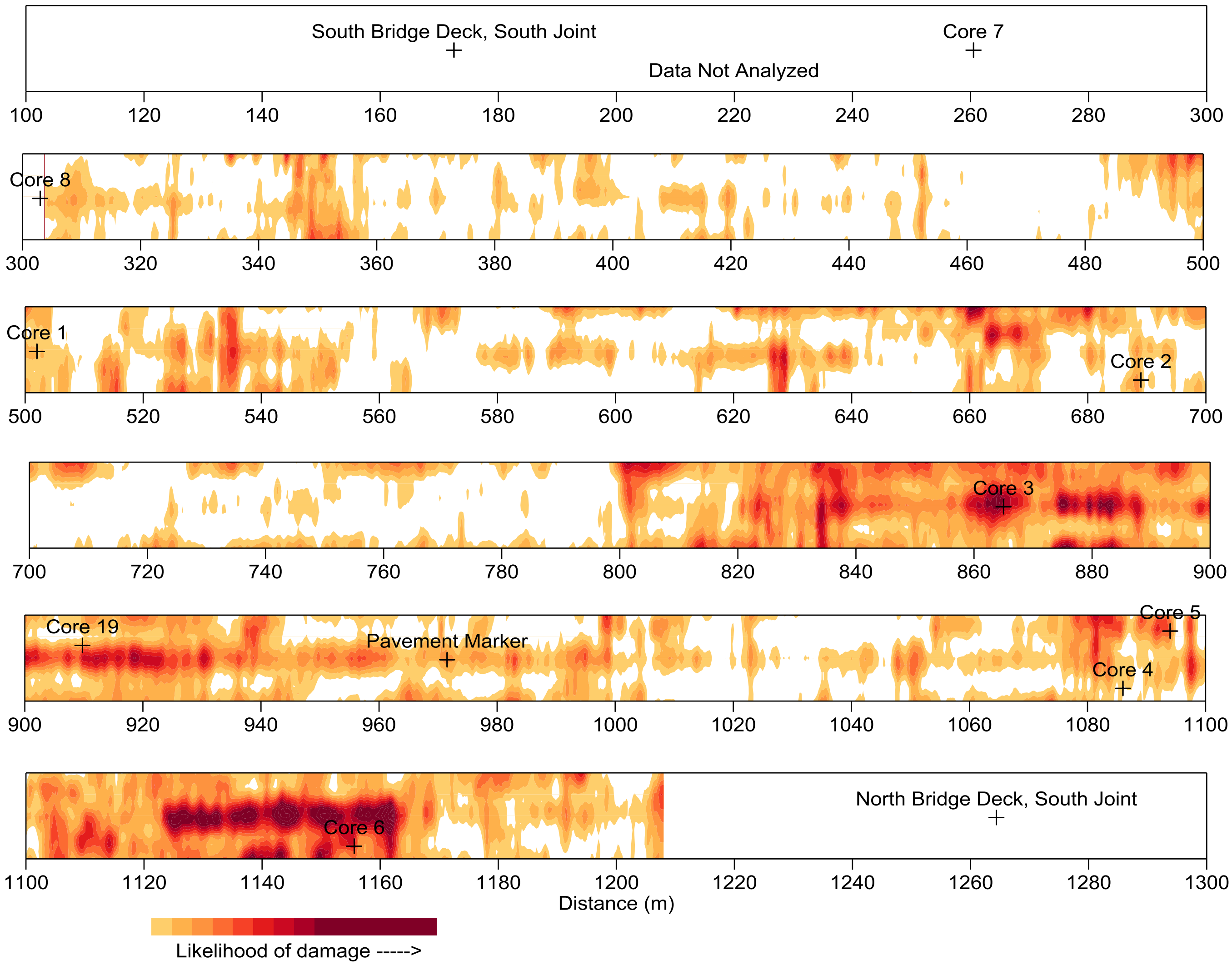


Figure 3.5. Sample GPR depth slice data at core locations 4 through 6.



Note: Core numbers are shown on plot.

Figure 3.6. Results of automated activity analysis (see Volume 1, Chapter 3, Uncontrolled Field Evaluation section).

CHAPTER 4

Kansas Cores Analysis: Coring Locations and Results for US-400 Pavement Site

Pavement sections with some delamination problems in four states were selected for uncontrolled field testing of the two nondestructive testing (NDT) techniques. However, because of some delays in equipment improvement, uncontrolled field testing did not begin until winter 2010 for the ground-penetrating (GPR) technique and until spring 2011 for the mechanical wave technique. Weather conditions were not suitable for field testing in Maine and Washington State. Therefore, the two NDT techniques were evaluated only on pavement sections in Florida and Kansas.

In Kansas, a westbound pavement section between Milepost (MP) 412 and MP 425.5 on US-400 was selected for high-speed GPR testing. Results of the high-speed GPR testing were then reviewed, and a pavement section of approximately 3,500 ft starting from MP 417.1 was selected for low-speed GPR testing. On the basis of core data provided by the Kansas Department of Transportation (KDOT), the pavement thickness of the long section varied from 13.5 to 19 in., and the pavement thickness of the short section was approximately 13.5 in. This section was a full-depth asphalt pavement. In 1988, an 8-in. dense-graded asphalt base layer was built on top of subgrade and then surfaced with a 2-in. asphalt layer. In 1991, this section was overlaid with an asphalt layer 1 to 1.5 in. thick. Another surface layer approximately 2-in. thick was placed on top of this section in 1999. The data also showed that all the cores cut from the short section broke at a depth of between 1.75 and 4.75 in. from the surface, and the base layer had a severe stripping problem.

After reviewing the GPR test results and other information provided by KDOT, the research team decided to conduct field testing of the mechanical wave technology on the same 3,500-ft section starting from MP 417.1. Locations where anomalies were identified in the GPR results were selected for lightweight deflectometer testing and cutting cores to verify the delamination condition. This chapter discusses the selection of coring locations and the results from testing cores in the laboratory.

Table 4.1 shows the locations where anomalies were found in the GPR results and where cores were extracted in the 3,500-ft pavement site starting from MP 417.1. Figures 4.1 and 4.2 show the anomalies and the locations of the first six cores in conjunction with the NDT test results. All the cores cut from the short section broke at a depth of between 1.75 and 4.75 in. from the surface, and the base layer had a severe stripping problem. Figure 4.3 shows that Core 6 broke during coring and had severe stripping problems in the lower layers.

Table 4.1. Locations of Anomalies and Cores for US-400 Pavement Site

Core	Distance (ft) from South Deck Joint	Offset	GPR Observation	Core Condition
1	1,080.8	CL	Anomaly	Stripped
2	1,694.2	RWP	Anomaly	Stripped
3	2,271.5	CL	Anomaly	Stripped
4	2,996.3	RWP	Anomaly	Stripped
5	3,022.6	LWP	Anomaly	Stripped
6	3,224.6	RWP	Anomaly	Stripped
7	288.8	CL	Anomaly	Stripped
8	427.9	CL	No anomaly	Stripped

Note: CL = centerline.

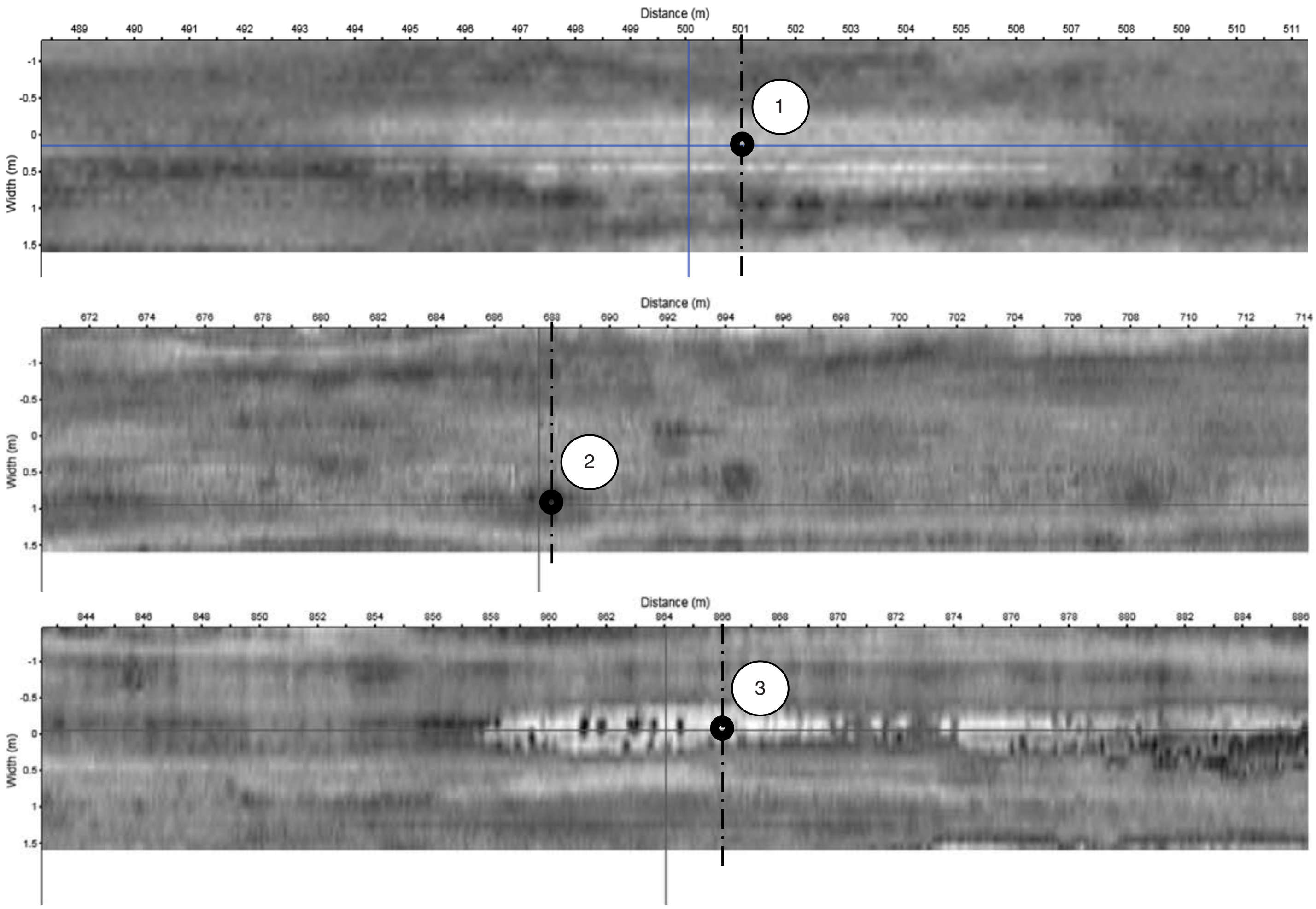


Figure 4.1. Locations of Cores 1, 2, and 3.

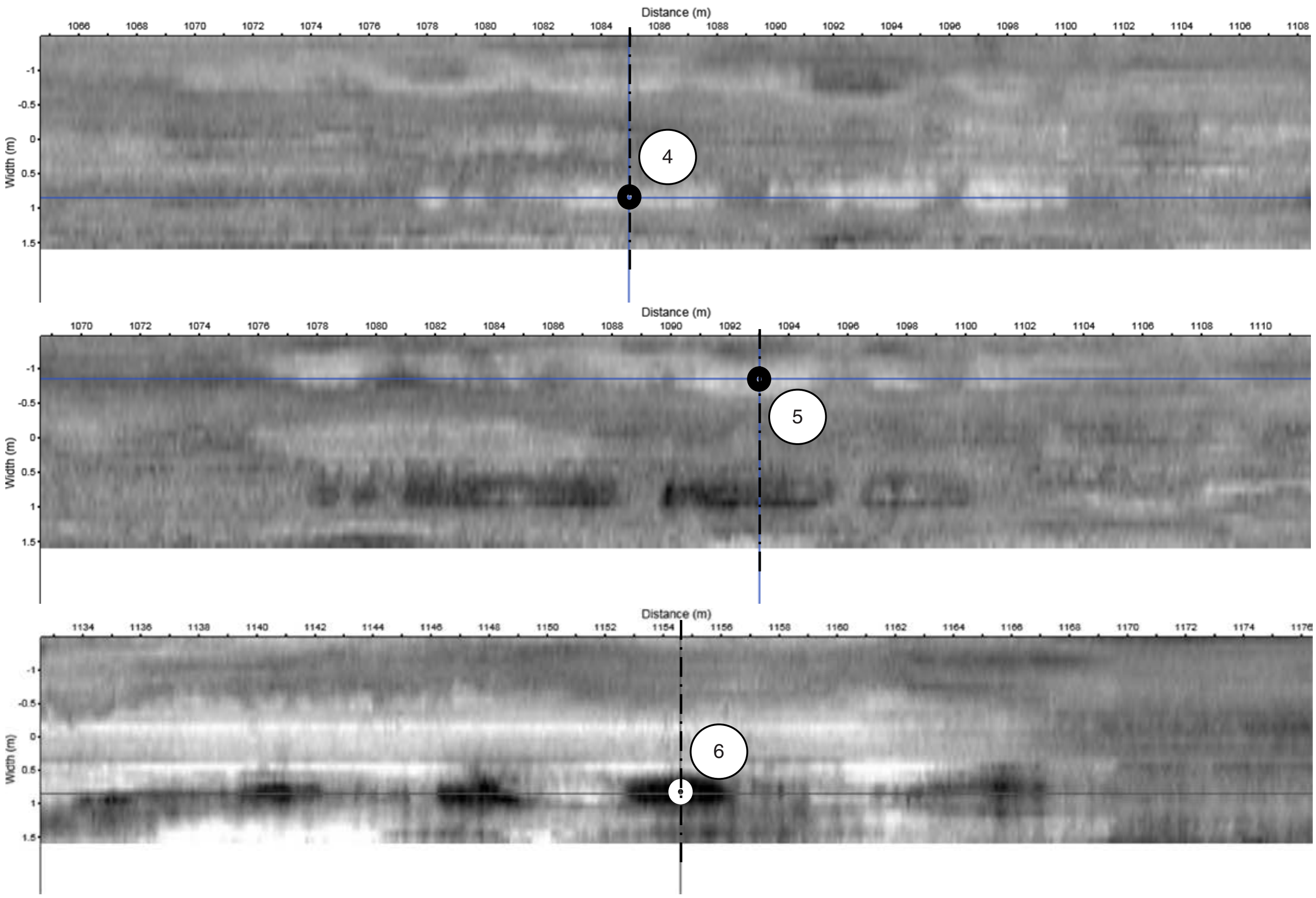


Figure 4.2. Locations of Cores 4, 5, and 6.

Figure 4.3. Severe stripping problems in Core 6.

*Membership as of April 2013.

Related SHRP 2 Research

Nondestructive Testing to Identify Concrete Bridge Deck Deterioration (R06A)

Evaluating Applications of Field Spectroscopy Devices to Fingerprint Commonly Used Construction Materials (R06B)

Using Infrared and High-Speed Ground-Penetrating Radar for Uniformity Measurements on New HMA Layers (R06C)

Real-Time Smoothness Measurements on Portland Cement Concrete Pavements During Construction (R06E)

Assessment of Continuous Pavement Deflection Measuring Technologies (R06F)

Mapping Voids, Debonding, Delaminations, Moisture, and Other Defects Behind or Within Tunnel Linings (R06G)